Water holding effect of subalpine dark coniferous forest soil in Gongga Mountain, China

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Abstract: Because of the distinction of soil property and humus content, soil water content is not ideal to indicate whether it is suitable to the growth of plant. Mainly based on the PF-a numerical value denoting the water regime of soil and connected with the growth of plant, the study combined the moisture percentage of soil with PF to research in quantity the interrelation between the moisture percentage and PF in different succession phases of subalpine dark coniferous forest in Gongga Mountain. The results showed that: (1) In the same PF value, the moisture percentage in humus horizon increased gradually with the development of the succession of the dark coniferous forest; The moisture percentage of over-mature forest was the highest and>mature forest>half-mature forest>young growth forest; (2) With the increase of soil depth, the soil bulk density increased and the moisture percentage decreased, but the difference in the percentage of moisture was not notable in different succession phases. (3) In different succession series, the vegetation affected the soil water characteristics by increasing the soil organic matter, improving the soil construction, receding the soil bulk density and enhancing the soil porosity; (4) The humus horizon of the dark coniferous forest soil has the highest water holding capability in this region.

Keywords: Gongga Mountain; Moisture percentage; PF value; Dark coniferous forest; Forest soil; Water-holding capability

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Introduction

Water conservation function of forest is a major part of its ecosystem functions, and the forest soil, whose structural properties can influence the soil water-physical characters, is a significant factor of its hydro-ecosystem functions (Cognard-Plancq *et al.* 2001; Zhao 2001; Gao 2000). By turning precipitation into groundwater, the forest soil retards the formation of surface runoff and regulates the streamflow to realize its hydrological function (Zheng *et al.* 2002). Soil plays an important role in the forest hydrological cycle. The physical characters of soil, especially its structure and its porosity, have a significant influence on the forest hydro-ecological benefit (Jing *et al.* 2002). The water holding capacity of forest soil relies mainly on soil texture and porosity. Because the differences of mechanical composition and structure of soil are notable under different forest types, just in the same forest type, with the changing of the succession, the soil's porosity condition is also varying greatly (Wu *et al.* 1997). This paper mainly concerned on the relationship between the soil physical structure and soil water conservation, as well as the relation between the soil water content and PF value. And primary study has shown that different kinds of forest soil may have same water content, but they have different available water, that is, different water conservation forms, will lead to the different effect on the growth of vegetation greatly (Shan 1986b; Shan *et al.* 1986a).

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Study area

Gongga Mountain is located in the transitional area in the southeast of Tibetan Plateau and the Sichuan Basin between 29°20'~30°20'N and 101°30'~102°15'E. It has a varied topography and contains the oceanic glacier of the lowest altitude in China. Because of its high altitude, the climate there changes more subtly than that of plain area, which influences significantly the stability of the upriver source of Yangtze River and the eco-environment of the middle and lower reaches of rivers (Wang *et al.* 2002). The Gongga Mountain research station is situated on the 3000-meter-high moraine tableland (on the left bank of Hailuogou), a fan-shaped trace deposited by mud-rock flow. The virgin forest succession gradient is very good here, having the Emei fir (*Abies fabris*) forest, the main body of the frigid-temperate-zone subalpine dark coniferous forest of the east slope of Gongga Mountain, including the Emei young growth fir forest (30-40 years old) of the initial succession stage, the Emei half-mature fir forest (70-80 years old) of the middle succession stage, the Emei mature fir forest (120 years old) and the Emei over-mature fir forest (150- years old) of the later succession stage. Tree com-

ponents are mainly *Abies fabri*, *Populua puesumii*, *Sorbus pohuashanensis*, *Betula albo-sinensis* and *Rhododendron* spp. There are little differences in soil textures of different forest succession series, most of which are forest sandy soil. It develops poorly and is very thin, with high content of sand and a strong permeability, whose hydrologic process is mainly the interflow. The climate in this area belongs to the frigid-temperate type, chilly and humid. The annual average temperature is 4°C, and average temperature in January is –4.5°C and 12.7°C in July. The annual rainfall is 1800-2100 mm, and 79.5% of which happens in rainy season.

Methods

Collocation of the samples

Based on the terrain feature of the soil of dark brown conifer forest in Gongga Mountain, setup 10m×10m sample plots in the young growth, half-mature, mature, and over-mature forest respectively.

Sample collection

Three samples are randomly collected in each sample site. Soil samples of vertical section (Zhao & Zhou *et al.* 2002; Instituted of Pedology 1995)—humus horizon, A horizon, B horizon and parent material horizon were collected by cylinder cutting (50 mm in inner diameter and 50 mm in height) under different Emei fir forest, Sealed them and measured them within two weeks.

Experiment methods

The water content of various kinds of soil with different PF was measured using a new-typed PF determining sandbox introduced from Netherlands. Its principle: under the known pressure (the known PF) and in the balanced condition (the balance takes one week for each PF), the soil water content with different PF value is determined by means of drying and weight stabilization. The soil water contents were measured by routine methods of weighing and drying (Zeng 1994). The moisture percentage (divide water weight by soil dry weight) of sample soil with different PF was calculated based on the experimental results. The equipment's measuring range was from 0 to 2.0. Its merits: when sand is used as absorbent, it has flexible sections; when the sample is replaced after weighing, the interface of the sand and the sample is easier to restore than using hard osmotic plate as absorbent.

Results and analysis

In Emei fir forest in Gongga Mountain, with the development of succession, the soil bulk density diminishes gradually; but with the increase of soil depth, it increases greatly. The diversity in soil bulk density reflects the difference of soil physical property; therefore it affects the water holding capability of forest soil (Fig.1).

The curve of PF to PM (moisture percentage of soil) not only reflects the amount of moisture but also the water conservation state. When in saturation state (PF=0), for example, the diversity of moisture percentage is notable in different succession phases, and this reflects the difference of water holding capability in succession phases (Zhou *et al.* 1994; Lei *et al* 1988). Vegetations in different forest ages function differently in improving forest soil, therefore the soil physical properties and the their water holding capabilities are changing greatly even in similar climate. And the moisture available for plant growth are different, hence appears different PF to PM curve.

Water conservation is mainly affected by total soil porosity, soil porosity, soil bulk density, soil organic matter, and soil grain construction (Jary 1991). With the development of dark coniferous forest in this region, the soil porosity increased gradually, but the bulk density decreased correspondingly. Therefore the water holding capabilities in different succession phases are distinct. In saturation state (PF=0), for instance, the moisture percentage in humus horizon of over mature forest, mature forest, half-mature forest and young growth forest were 514.41%, 449.78%, 341.17% and 245.99% respectively. When PF is 2.0 (the moisture percentage is suitable for plants to grow), the highest values in humus horizon of over-mature forest, mature forest, half-mature forest and young growth forest were 98.94%, 90.68%, 100.05% and 80.60% respectively.

With the development of dark coniferous forest and the decrease of soil depth, soil water content increases gradually. Water holding capability is the highest in humus horizon. With the increase of soil depth, the moisture percentage recedes. However, the changes among percentages of moisture are not significant in succession phases (as shown in Table.2 and Fig.1).

Discussion

With the succession of subalpine dark coniferous forest in Gongga Mountain, the physical characters and water holding capability of soil have changed obviously. Forest vegetation affects soil water holding capability mainly by increasing the soil organic matter, improving the soil construction, receding soil bulk density and enhancing the soil porosity. To increase the eco-environmental benefits of water conservation in Gongga Mountain, we must firstly protect original Emei fir forest and their soil.

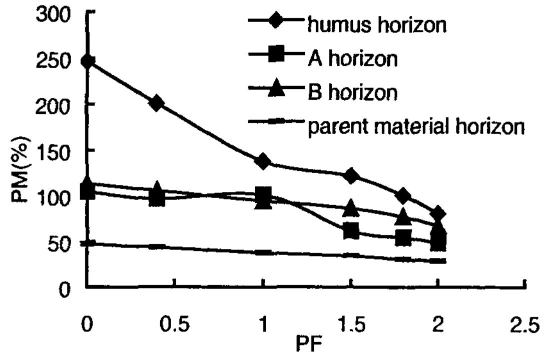
(1) The forest soil bulk density is the important factor in soil physical characters, and with the development of forest succession and the decrease of the soil depth, it reduces greatly. This study showed that in different succession phases, the dark coniferous forest affected the soil physical characters, and this resulted in different soil physical characters in different succession phases.

Table 1. Soil weight, dry weight and bulk density in various Emei fir forest with different PF

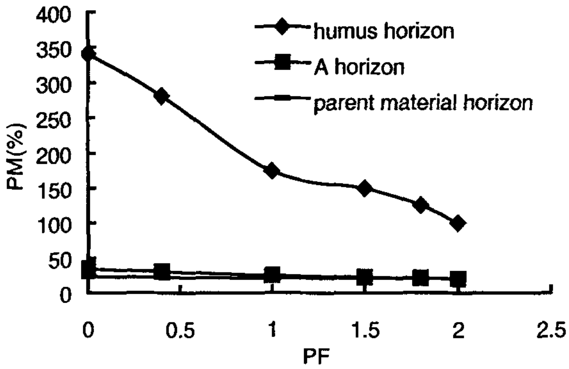
Forest series		Horizon	Soil weight in different PF values						Dry weight	Soil bulk density
			PF=0	PF=0.4	PF=1.0	PF=1.5	PF=1.8	PF=2.0		
Young growth	1	Humus	101.48	88.33	69.85	65.13	58.88	52.97	29.33	0.30
		A	132.52	127.31	130.17	104.67	99.75	96.07	64.76	0.65
		B	139.08	133.92	126.40	121.24	115.29	108.48	65.01	0.67
		Parent material	164.94	161.19	154.39	150.72	146.50	144.09	112.12	1.12
Half-mature	2	Humus	91.72	79.39	57.18	51.95	46.90	41.59	20.79	0.22
		A	161. 92	156.83	150.90	147.36	145.67	144.29	120.18	1.21
		Parent material	199.06	196.78	195.90	195.44	194.97	194.84	161.50	1.62
	3	Humus	102.17	89.66	70.89	66.58	60.15	56.33	29.51	0.31
		A	181.10	179.37	171.71	167.39	164.53	161.98	124.42	1.25
		Parent material	168.72	157.84	156.03	154.68	152.05	151.24	107.59	1.08
Mature	4	Humus	86.04	77.59	45.93	40.51	34.31	29.42	15.65	0.17
		A	153.40	151.00	146.23	144.99	142.84	142.53	95.72	0.96
		B	187.52	185.03	184.18	182.82	182.37	180.91	146.68	1.47
	5	Humus	90.97	75.45	54.69	50.87	43.05	35.81	18.78	0.20
		A	149.18	144.37	140.35	138.56	136.59	135.78	108.25	1.08
		Parent material	168.24	164.55	163.52	161.58	160.30	159.74	127.97	1.29
Over mature	6	Humus	83.99	69.89	46.43	42.10	35.43	26.75	13.67	0.18
		A	160.2	152.42	151.80	151.60	150.36	149.49	106.24	1.06
		B	174.97	173.18	172.83	172.00	171.92	169.68	135.61	1.35
		Parent material	180.71	178.36	175.32	172.39	171.58	169.82	143.68	1.44
	7	Humus lay	75.18	58.11	41.85	37.05	30.12	26.26	13.20	0.13
		A	137.31	128.67	123.26	120.81	117.38	115.89	89.64	0.90
		B	147.67	144.14	141.08	139.22	135.00	111.35	95.92	1.11
		Parent material	150.97	144.15	141.39	139.58	136.57	135.89	120.47	1.20

Table 2. Soil sample's moisture percentage in different PF in Emei fir forest

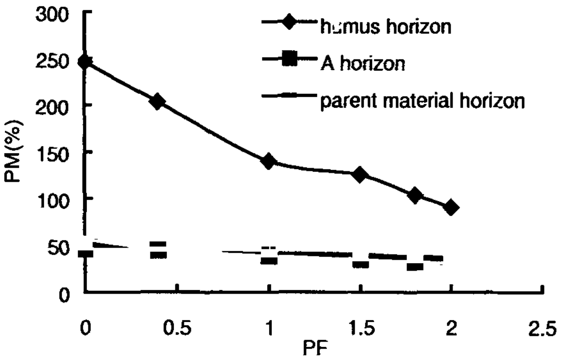
Forest series		Horizon	Moisture Percentage in different PF					
			PF=0	PF=0.4	PF=1.0	PF=1.5	PF=1.8	PF=2.0
Young growth	1	Humus	245.99	201.16	138.15	122.06	100.75	80.60
		A	104.63	96.59	101.00	61.63	54.03	48.35
		B	113.94	106.00	94.43	86.49	77.34	66.87
		Parent material	47.11	43.77	37.70	34.43	30.66	28.51
Half-mature	2	Humus	341.17	281.87	175.04	149.88	125.59	100.05
		A	34.73	30.50	25.56	22.62	21.21	20.06
		Parent material	23.26	21.85	21.30	21.02	20.72	20.64
	3	Humus	246.22	203.83	140.22	125.62	103.83	90.88
		A	45.56	44.16	38.01	34.54	32.24	30.19
		Parent material	56.82	46.71	45.02	43.77	41.32	40.57
Mature	4	Humus	449.78	395.78	193.48	158.85	119.23	87.99
		A	60.26	57.75	52.77	51.47	49.23	48.90
		B	27.84	26.15	25.57	24.64	24.33	23.24
	5	Humus	384.40	301.76	191.21	170.87	129.23	90.68
		A	37.81	33.37	29.65	28.00	26.18	25.43
		Parent material	31.47	28.58	27.78	26.26	25.26	24.83
Over-mature	6	Humus	514.41	411.27	239.65	207.97	159.18	95.68
		A	50.79	43.47	42.88	42.70	41.53	40.71
		B	29.02	27.70	27.45	26.83	26.78	25.12
		Parent material	25.77	24.14	22.02	19.98	19.42	18.19
	7	Humus	469.55	340.23	217.05	180.68	128.18	98.94
		A	53.18	43.54	37.51	34.77	30.95	29.28
		B	32.62	29.45	26.70	25.03	22.73	21.24
		Parent material	25.32	19.66	17.37	15.86	13.36	12.80



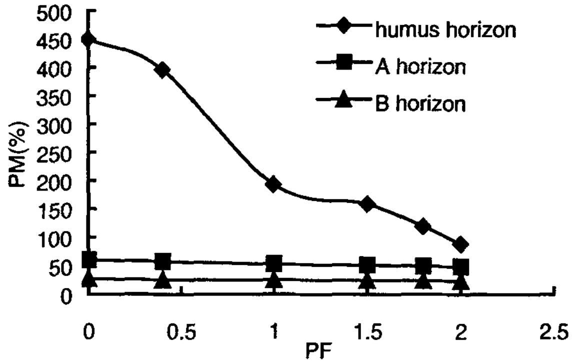
PF to PM curve of young growth forest(1)



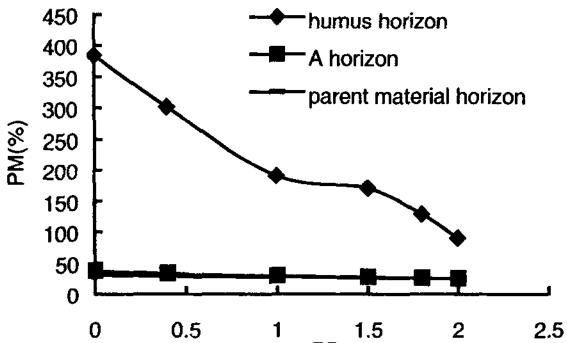
PF to PM curve of half-mature forest(2)



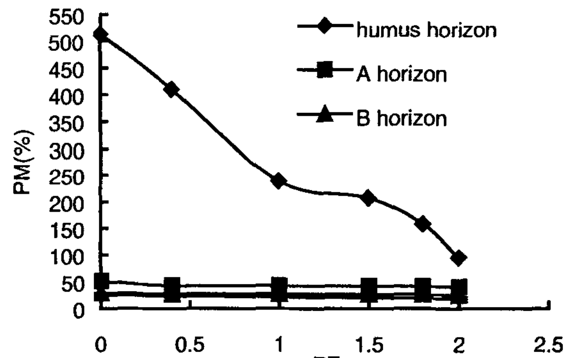
PF to PM curve of half-mature forest(3)



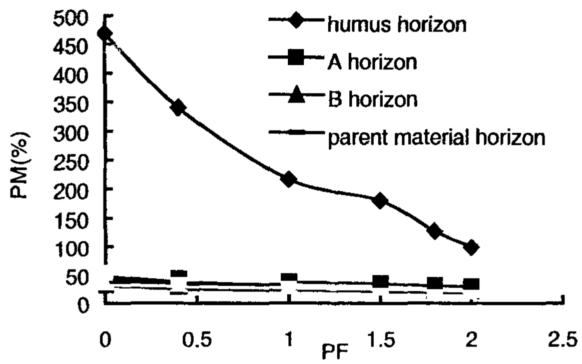
PF to PM curve of mature forest(4)



PF to PM curve of mature forest(5)



PF to PM curve of over- mature forest(6)



PF to PM curve of over -mature forest(7)

Fig. 1 PF to PM (moisture percentage) curve in different forest succession phases

(2) Soil water holding capability of dark coniferous forest conforms to certain orderliness, the value of soil water holding capability is: over-mature forest >mature forest>half-mature forest>young growth forest. Forest protection, especially over-mature forest and mature forest conservations are very important in soil water holding capability in this areas.

(3) In this region, the humus horizon of dark coniferous forest has the highest water holding capability, and the benefit of water conservation in different succession phases differ significantly. With the progressive succession, as in saturation state (PF=0), the highest values of the moisture percentage in humus horizon were up to 245.99%, 341.17%, 449.78% and 514.41%, respectively. Protection of the humus horizon in Emei fir forest will be the beneficial way to the forest water conservation.

(4) With the increase of the soil depth, the moisture percentage of soil reduces: humus horizon's>A horizon's>B horizon's>parent material horizon's. This showed that in the forest soil, most of water holding by Emei fir forest mainly distributed in the upper horizon.

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